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# BOLOMETRIC MEASUREMENTS OF RELIC RADIATION

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# BOLOMETRIC MEASUREMENTS OF RELIC RADIATION

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ABSTRACT: The feasibility of an alternative approach to measuring anisotropy, based on the use of wideband receivers, is examined. The method of measuring the velocity of the observer relative to the frame of reference, connected to the relic background is illustrated by way of example of Planckian spectrum and can be employed for non-Planckian spectrum of relic radiation.

Direct measurements and indirect estimates of the brightness of cosmic backgrounds in the 75-0.33 cm wavelength range has shown that the relic radiation spectrum is described by the Planck function as temperature of 2.65°K. The question of the degree and character of anisotropy, if there is any, of the background is very important in cosmology. However, the predicted manifestations of anisotropy of cosmic origin [1] have been fewer than the apparent anisotropy, toward which the observer moves with the galaxy, Sun and Earth relative to the motion of the frame of reference connected to the background. /3*

The search for anisotropy [2] is conducted with a narrow band receiver in the Rayleigh-Jeans region of the spectrum as relic radiation, where the brightness temperature ($B_\nu \sim T$) is the recorded value. The purpose of this article is to focus attention on the feasibility of an alternative approach to measuring anisotropy, based on wideband receivers. Bolometers are capable of measuring the integral brightness of the background, which is more sensitive to variations

*Numbers in the margin indicate pagination in the foreign text.

of the visible temperature ($B \sim T^4$). Furthermore, it becomes possible to measure the autocorrelation function (ACF) of radiation and its dependence on the orientation of the observer. Both advantages are realized in Fourier--spectrometry, where the trace on the interferogram at zero calibration is determined by the integral background brightness, and the interferogram itself is proportional to the ACF (assuming ideal beam separation). The dependence of the optical difference of the trace at the point of change of the sign of the ACF on the velocity of the observer and the orientation of the observer is obtained. /4

If the observer travels relative to the background at velocity $V = \beta c$ the brightness is expressed by the equation:

$$B_G = \frac{2n}{C^2} \frac{\nu^3}{\varepsilon^{\frac{h\nu}{kT(\alpha,\beta)}} - 1}, \tag{1}$$

where

$$T(\alpha,\beta) = T_0 \frac{1 + \beta\cos\alpha}{\sqrt{1 - \beta^2}}.$$

$\alpha$ is the angle between the vector $\overline{V}$ and the direction of the observer,

$c$ is the velocity of light, $h$ is the Planck constant, $k$ is the Boltzmann constant. Thus the brightness perceived by the observer ceases to be isotropic. The maximum brightness difference in the Rayleigh-Jeans region ($h\nu \ll kT$) is equal to the difference of the readings in the direction $\alpha = 0$ and $\alpha = \pi$.

$$\frac{\Delta B_\nu}{B_\nu} = \frac{\Delta T}{T_0} = \frac{2\beta}{\sqrt{1 - \beta^2}}, \tag{2a}$$

The visible anisotropy is apparently more pronounced for integral brightness proportional to $[T(\alpha,\beta)]^4$. The maximum difference of integral brightness is

$$\frac{\Delta B}{B} = \frac{8\beta(1 + \beta^2)}{(1 = \beta^2)^2}, \tag{2b}$$

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when $\beta \ll 1$ is four times greater than (2a).

For Planck radiation at 3°K $B \simeq 7.3 \cdot 10^{-11}$ W/cm$^2$ ster and with a receiver sensitivity of $10^{-14}$W and luminosity of 1 cm$^2$ster the minimum detected brightness relative to the background is $\beta = 2.5 \cdot 10^{-5}$ (V = 6 km/sec).

We will examine the changes experienced by the ACF of radiation with spectrum (1). The variable portion of the interferogram, recorded in the Michaelson interferometer has the form:

$$I(\Delta) = \int_0^\infty B_\nu \cos\left(\frac{2\pi\nu\Delta}{c}\right) d\nu ,$$

where $\Delta$ is the optical difference of the trace in the interferometer. Computation of the integral yields (3):

$$I(\Delta) = \frac{\sigma(T(\alpha,\beta))^4}{2\pi} \, 15 \, \frac{3x^4 + 2\pi^4 sh^2 x - 3 sh^4 x}{x^4 sh^4 x}$$

$$\chi = \frac{2\pi^2 kT(\alpha,\beta)}{ch} \Delta, \qquad (3)$$

where $\sigma$ is the Stefan-Boltzmann constant. The graph of this function is depicted in the figure.

As follows from (3), the difference of the trace $\Delta_0(\alpha,\beta)$ at the zero point of the interferogram, where the ACF changes sign, depends on $\alpha$ and $\beta$ as follows:

$$\Delta_0(\alpha,\beta) = \Delta_0(1 - \beta \cos \alpha),$$

where

$$\Delta_0 = \frac{1.37\, ch}{2\pi^2 kT} .$$ /7

With this function it is possible to substitute the energy measurements during the search for anisotropy by measurements of the difference of the ray traces in the Michaelson interferometer. The maximum displacement of the ACF zero from $\Delta_0$ = 334.80 μ (T - 2.75°K, β = 0), occuring in directions α = 0 and α = π, is about 0.06 μ for $\beta = 10^{-4}$ (V = 30 km/sec). The corresponding change in the signal is $\sim 1.4 \cdot 10^{-14}$ W with a luminosity of 1 cm ster, which is close to the limiting capabilities of the equipment [14].

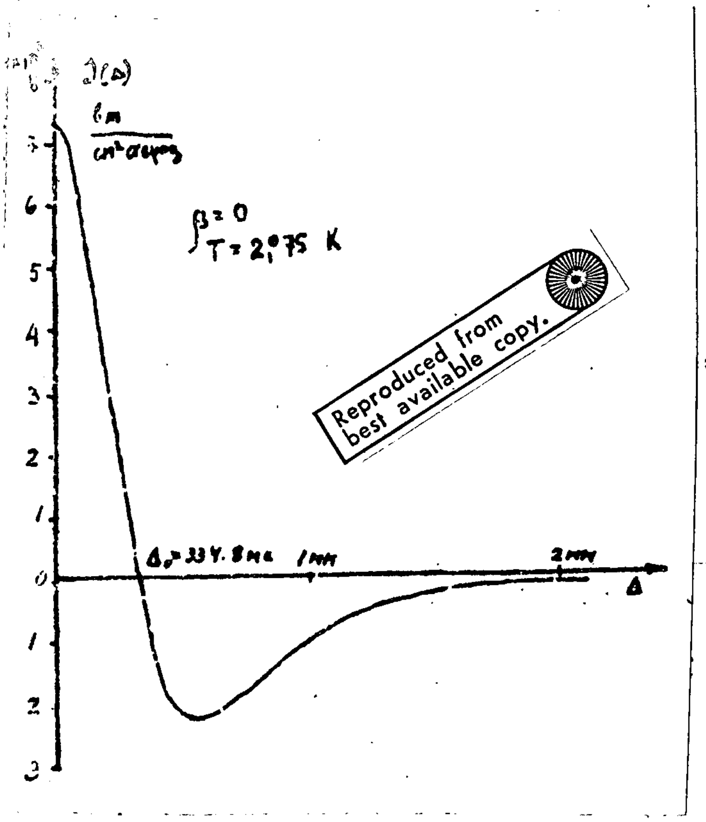



Figure. Autocorrelation Function of Planck Radiation t = 3°K.

The above-examined methods of measuring the velocity of the observer relative to the frame of reference, connected with the relic background, which we have illustrated by way of example of the Planckian spectrum, can also be used in like fashion for non-Planckian spectrum of relic irradiation.

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